Death becomes them

the end of Sun-like stars

Stars are born, live, and die, in a majestic cycle that turns matter into energy in the course of billions of years. Driven by the relentless force of gravity, and shining through nuclear fusion in their cores, stars contract from immense clouds of tenuous interstellar matter, radiate brightly, and then die in a brief blaze.

The final phases of stars are especially interesting, because it is then that up to 40% of the star is blown back into space. This gas is enriched with heavy elements such as carbon, oxygen and nitrogen that formed from hydrogen by the nuclear fusion that makes the star shine. We are made of such stuff.

A low-mass star such as our Sun becomes unstable after about ten billion years of shining quietly. Then its core contracts and the outer atmosphere of the star swells up to a size at least as big as the orbit of Venus. This dense cool gas blows away and then, in a final gasp, the remaining stellar core throws off a tenuous whiff of searingly hot and fast-moving gas. Hurtling outward at over a thousand kilometres a second, this fast wind smashes into the slow wind that preceded it. The collision compresses a shell, brightly illuminated by the very hot remains of the dead star in the centre.

The resulting object has become known as a *planetary nebula*, because it vaguely resembles a planet when seen in a small telescope.

But things are not as simple as the above may lead one to believe. Planetary nebulae are not just spherical shells. Most of them have funny shapes, such as elliptical or very elongated ('bipolar'). In the early '80s Bruce Balick (University of Washington, USA) attempted to classify all known shapes in a single unifying scheme. The idea was that perhaps bipolar nebulae were closely related to the spherical ones, made elongated by some as yet unknown mechanism.

Balick started a collaboration with Vincent Icke (University of Leiden, The Netherlands) to investigate this problem. Soon Icke proved that Balick's scheme works, provided that the slow stellar wind is not spherical but slightly flattened. This is not at all odd; after all, our Solar System is very flat, and it stands to reason that the ejected cloud at the end of the Sun's life would be a little flattened, too.

Icke extended his analytical calculations by numerical hydrodynamical computations. The results, confirmed and extended by Garrelt Mellema (Stockholm University) and Adam Frank (University of Rochester), predicted that the bipolar planetary nebulae would fall in a range of shapes from perfectly spherical to highly elongated.

From the numerical computations they predicted that the fast wind from the dying star would be focused into two narrow streams or jets. Now, almost nine years after that prediction, the spectacular observations made with the Hubble Space Telescope appear to confirm the hydrodynamic models in almost every detail. This sets the stage for a new round of even more detailed theoretical investigations into the nature of these beautiful remains of dying stars.

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